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APPLICATION OF INTEGRATED MULTI TROPHIC AQUACULTURE SYSTEM MODEL TO REDUCE WASTE ORGANIC MATERIALS

Penerapan Model Sistem *Integrated Multi Trophic Aquaculture* Untuk Menurunkan Limbah Bahan Organik

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ABSTRACT

The use of intensive aquaculture systems is one of the activities that provide an overview of aquaculture to increase production due to the high stocking density of fish but has an impact on the contribution of waste from fish farming. Overcoming existing problems with the application of the Integrated Multi Trophic Aquaculture system cultivation model, this system is expected to help reduce cultivation waste. The purpose of this study is to determine how the IMTA system can help reduce organic waste in the aquatic environment so that water quality can be maintained and suitable for the life of organisms. This research was conducted from June to July 2023, at the Center for the Study and Development of Regional Excellence and Empowerment of Coastal Communities. The method used was descriptive quantitative. The results of the TOM analysis value in all treatments decreased. in treatment A 21.1 mg/l, B 41.0 mg/l and C 34.7 mg/l. TSS decreased differently every time, especially on day 42 for treatment A 0.031 mg/l, B 0.023 mg/l and C 0.178 mg/l. Ammonia for day 42 also decreased, namely in treatment A 0.03 mg/l, B 0.20 mg/l, C 0.13 mg/l. On day 42 nitrate for treatment A 0.03 mg/l, B 0.06 mg/l, C 0.08 mg/l. Water quality parameters for temperature, salinity, dissolved oxygen and acidity had reasonable values for all biota reared. Conclusion The IMTA system can help reduce organic waste of TOM, TSS, ammonia and nitrate, in addition, it can also reduce the amount of organic waste.

Key words: Implementation, Model, Integrated Multi Trophic Aquaculture, Waste, Organic material

ABSTRAK

Penggunaan sistem budidaya intensif menjadi salah satu kegiatan yang memberikan gambaran tentang budidaya agar dapat meningkatkan produksi karena tingkat padat penebaran ikan yang tinggi tetapi akan berdampak pada sumbangan limbah sisa hasil budidaya dari ikan yang dipelihara. Pendekatan yang dapat dilakukan untuk mengatasi masalah yang ada yaitu penerapan model budidaya sistem *Integrated Multi Trophic Aquaculture* (IMTA), dimana sistem ini diharapakan dapat membantu untuk menurunkan limbah hasil budidaya. tujuan untuk mengetahui bagaimana sistem IMTA dapat membantu menurunkan limbah organik pada lingkungan perairan sehingga kualitas air dapat terjaga dan layak untuk kehidupan organisme. Penelitian ini dilaksanakan dari bulan juni sampai dengan juli 2023, di Pusat Kajian Unggulan Daerah Dan Pengembangan Pemberdayaan Masyarakat Pesisir. Metode digunakan deskriptif kuantitatif. Hasil penelitian nilai analisi TOM pada semua perlakuan mengalami penurunan. pada perlakuan A 21,1 mg/l, perlakuan B 41,0 mg/l dan perlakuan C 34,7 mg/l. Nilai TSS mengalami penurunan yang berbeda tiap waktu terutama pada hari 42 untuk perlakuan A 0.031 mg/l perlakuan B 0,023 mg/l dan perlakuan 0.178 mg/l. Nilai amonia untuk hari ke 42 mengalami juga penurunan perlakuan A 0,03 mg/l, perlakuan B 0,20 mg/l, perlakuan C 0,13 mg/l. Pada hari 42 nilai nitrat untuk perlakuan A 0,03 mg/l, perlakuan B 0,06 mg/l, perlakuan C 0,08 mg/l. Parameter kualitas air untuk suhu, salinitas, oksigen terlarut dan Derajat keasaman memiliki nilai yang layak untuk semua biota yang dipelihara. Kesimpulan adalah sistem IMTA dapat membantu untuk menurunkan limbah bahan organik penurunan nilai TOM, TSS, amonia dan nitrat selain itu parameter kualitas air juga berada pada keadaan yang layak.

Kata Kunci: Penerapan, Model, IMTA, Limbah, Bahan organik

INTRODUCTION

The concept of sustainable cultivation is that it can provide large production results to meet consumer demand. The use of an intensive cultivation system is one of the activities that provides an overview of cultivation in order to increase production because of the high density of fish stocking but will have an impact on the contribution of waste from the remaining cultivation results from the fish being raised. Existing waste if not managed properly will have a negative impact on water quality and also the organisms being raised. The approach that can be taken to prevent the problems that occur is the application of the *Integrated Multi Trophic Aquaculture* (IMTA) system cultivation model, where this system is expected to help reduce waste from cultivation. Because IMTA is a cultivation system that utilizes more than one organism that has a symbiotic relationship in a food chain in a certain area and time together. So cultivators can maintain organisms in a certain area at the same time and provide mutual benefits (Triarso & Putro, 2019).

Environmentally friendly cultivation activities will help the development of a cultivation system with a high level of production. IMTA system cultivation is an innovation in mariculture cultivation practices. But it must pay attention to several different species with trophic levels in a food chain such as combining several commodities such as snapper, sea cucumber and seaweed in one cultivation location to be able to increase production and add economic value through water quality management and the occurrence of ecosystem balance (Firdaus *et al*., 2016). The use of each species is different in the IMTA system so that it is expected to maintain ecosystem balance naturally because each organism has its own function and role. Then the ability to recycle waste from the cultivation process which will be a source of energy and nutrients that are donated to other organisms. So that the results of the cultivation products will increase.

Fish farming activities in the sea usually people provide feed but not all feed can be consumed by fish so that the remaining feed will be wasted into the waters. in addition, the results of the metabolic process released by fish will also be disposed of in the waters, which will cause the emergence of organic waste from cultivation activities. The waste produced contains nitrogen and phosphorus elements which will help increase water fertility (Kusen, 2014). However, if nitrogen and phosphorus elements are excessive in the waters, it will have a bad impact, namely a decrease in water quality and disrupt the lives of organisms so that they must be managed properly. Marine cultivation activities with the IMTA system are designed to overcome environmental problems caused by cultivation activities (Yuniarsih *et al*., 2014). The results of the study showed that only a little of the feed given to fish can be eaten while the rest can pollute the aquatic environment. (Mustofa *et al*., 2018).

Aquaculture activities can produce unwanted waste because they can reduce and damage the condition of the aquatic ecosystem. Aquaculture activities require feed as an input so that they can produce a valuable product. In reality, there will always be waste problems in the cultivation system starting from feeding, metabolic activities and also unused feed by-products will result in environmental conditions being disrupted. (Dauda *et al*., 2019), The waste produced if not managed properly and correctly will have a negative impact on the environment, for example sedimentation and decreased water quality caused by waste contamination from leftover feed and fish feces (Aonullah *et al*., 2024). From the various waste pollution problems that occur due to cultivation activities, this study was conducted with the aim of finding out how the IMTA system can help reduce organic waste in the aquatic environment so that water quality can be maintained and is suitable for the life of organisms.

METODE PENELITIAN

The research was conducted from June to July 2023, at the Center for Regional Excellence Studies and Coastal Community Empowerment Development (Field Station Marine Science) Pattimura University, see Figure 1.

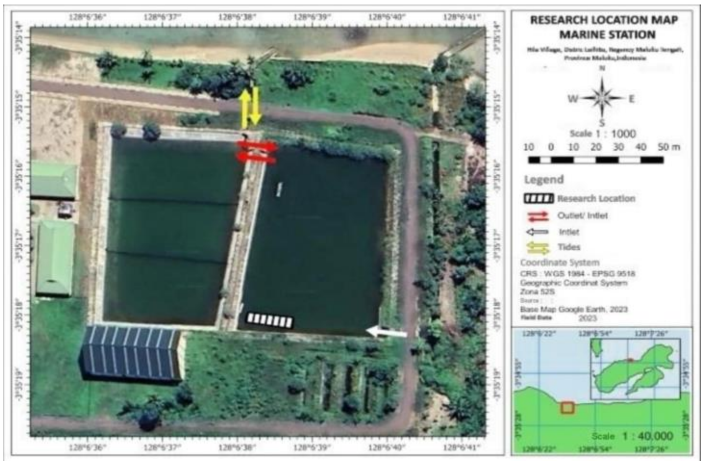

Figure 1: Research Location Map

The tools and materials used during the research can be seen in Table 1 and Table 2 below:

Table 1. Tools used during the research

No	Tools	Amount	Uses
1.	Plastic Bottle	18 pieces	As a container for taking test samples (water)
2.	pH meter	1 piece	To measure water pH
3.	Thermometer	1 piece	To measure water temperature
4.	DO meter	1 piece	To measure dissolved oxygen
5.	Refractometer	1 piece	To measure salt content
6.	Sewing needle	2 pieces	To sew nets
7.	Wood	36 sticks	As a floating net frame pole
8.	Carpentry Tools	1 unit	To make a KJA frame from sago fronds

9.	Net	18 pieces	As a container for cultivating biota in the IMTA system
10.	Nylon rope	1 roll	To hold the net in the IMTA system design system

Table 2. Materials used during the research

No	Materials	Quantity	Uses
1.	Seawater	Sufficient	As a test sample
2.	Tissue	1 pack	To wash tools after use
3.	Label paper	9 sheets	As a treatment marker
4.	Black sea cucumber	36 tails	As a test biota
5.	Seaweed	30 bags	As a test biota
6.	White Snapper Seeds	900 tails	As a test biota

Container Preparation

The maintenance container to be used is a floating net cage divided into 9 boxes for fish maintenance and lined with a net with a size below the fish net for sea cucumber maintenance. The cultivated organisms to be used in the IMTA system include white snapper (*Lates calcarifer*), seaweed (*Gracilaria salicornia*) and black sea cucumber (*Holothuria atra*). The white snapper to be used is 2-3 cm in size. The sea cucumber obtained weighs between 40-60g and while the seaweed sample is tied in one bag/50 g.

Commodity Maintenance

Feed is given to white snapper as the main commodity or the highest trophic level. The remaining feed that is not eaten by white snapper will be utilized by the cultivated organisms that are below and have a lower trophic level.

Water Quality Control

Water quality measurements are carried out every day. The measurements of water quality during maintenance are measurements of temperature, salinity, dissolved oxygen and water pH. Meanwhile, water samples are in the form of total organic matter (TOM) analysis at the beginning, middle and end of the study while total suspended solids (TSS), ammonia and nitrate will be tested every 14 days.

Research Design

The experimental design used was a completely randomized design (CRD) with 3 treatments and 3 replications. Treatment A (stocking density of white snapper fish 50, seaweed 10 bundles/50 gr, and black sea cucumber 4), Treatment B (stocking density of white snapper fish 100, seaweed 10 bundles/50 gr, and black sea cucumber 4), Treatment C (stocking density of white snapper fish 150, seaweed 10 bundles/50 gr, and black sea cucumber 4).

Data Collection Method

Data collection in this study, namely water quality parameter data during maintenance, namely temperature, pH meter, salinity, and dissolved oxygen were obtained from daily water quality measurements. Meanwhile, TOM data was taken at the beginning, middle and end of the study, while TSS, ammonia and nitrate data were measured at 14-day intervals during the study period.

Data Analysis Methods

The data analysis method used in the research is the quantitative descriptive method.

RESULT

Based on the results of the analysis of the total organic matter (TOM) value in the IMTA cultivation system, there were differences for each treatment which can be seen in Figure 2.

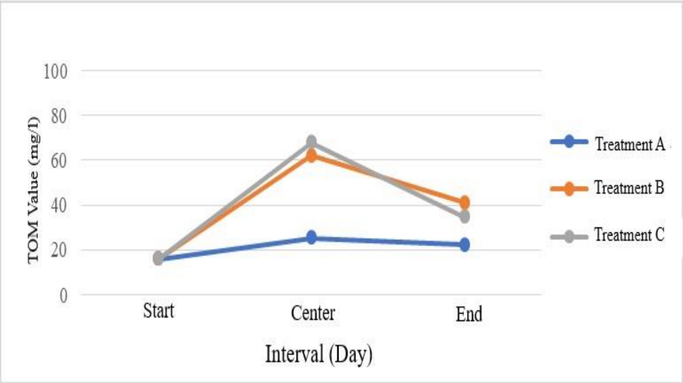

Figure 2. TOM Values During Research

The results of the analysis of total suspended solids (TSS) values in the IMTA cultivation system for each treatment experienced changes which can be seen in Figure 3.

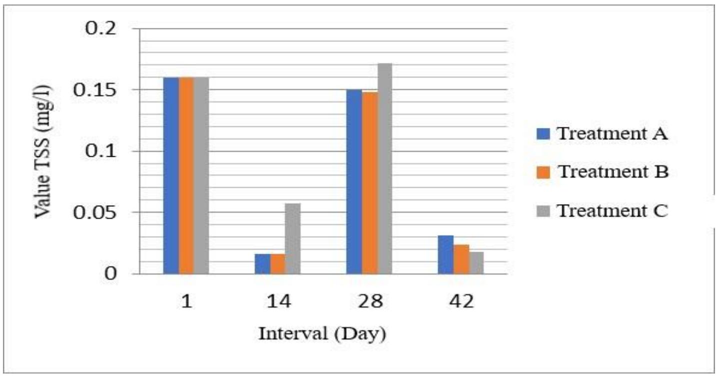

Figure 3. TSS Values During Research

Based on the analysis results, the ammonia value in the IMTA cultivation system for each treatment experienced changes, as seen in Figure 4.

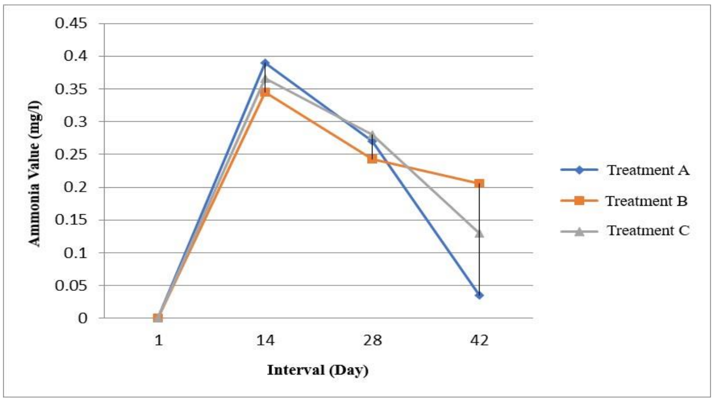

Figure 4. Ammonia Values During Research

The results of the nitrate value analysis show differences in each treatment of the IMTA cultivation system and can be seen in Figure 5.

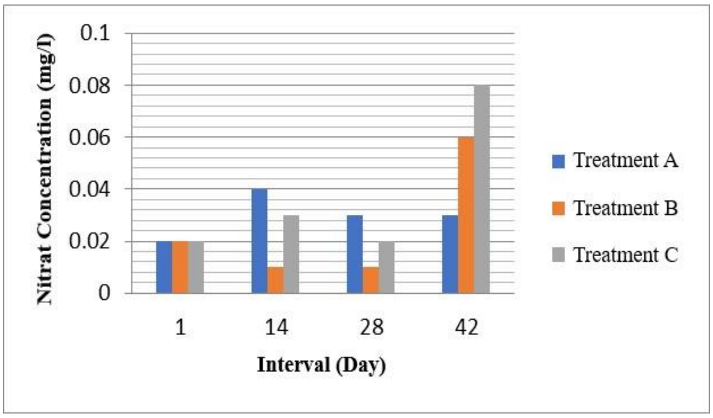

Figure 5. Nitrate Values During Research

The results of water quality parameter measurements during the study, namely temperature, salinity, dissolved oxygen and acidity levels in the IMTA cultivation system can be seen in Table 3.

Table 3. Water Quality Parameter Values During Research

No.	Parameters	Unit	Value
1	Temperature	° C	27,9 - 28.6
2	Salinity	ppt	19-30
3	Dissolved Oxygen (DO)	mg/l	5,9 - 6,7
4	Acidity (pH)		7,2 - 7,7

DISCUSSION

Organic matter is one of the determinants of fertility in an aquatic environment. Certain levels can function for the activity of aquatic biota, but if the amount exceeds the threshold level in the water, it will interfere, resulting in a decrease in water quality from the decomposition process of organic matter. The results of the TOM value test at the beginning of the study for each treatment A, B and C had a value of 15.0 mg/l. The value obtained is thought to be due to the presence of organic matter in the waters originating from dissolved, suspended and colloidal organic matter. During the maintenance period, the highest TOM value occurred in the middle of the study, namely treatment B with a value of 62.2 mg/l and treatment C was 67.9 mg/l, while it decreased for treatment A by 25.2 mg/l. This is thought to be due to the denser the fish kept, the higher the contribution of organic matter from feeding and metabolic waste in the form of feces from farmed fish. Waste from unconsumed pellets and fish feces from cultivation activities that will sink to the bottom because they have a higher density than the water around the floating net cages. (Gustiyo, 2021). However, the TOM value in all treatments decreased at the end of the study. in treatment A it was 21.1 mg/l while treatment B was 41.0 mg/l and treatment C was 34.7 mg/l. This shows that sea cucumbers can utilize organic waste as organisms that have a lower trophic level. Organic matter in the substrate is a food source so it is utilized by sea cucumbers. Sea cucumbers in nature get their main source of food from the organic content in mud, detritus (decomposing organic matter), and plankton. (Pattinasarany & Manuputty, 2018). Sea cucumbers are one of the organisms needed in the IMTA system because they are able to suppress particulate waste produced by other animals. (Zamora *et al*., 2016). Sea cucumbers are also known as sediment-eating animals, then the remains of organic matter, bacteria and microalgae found in the sediment/substrate become their main food.

Pollution in waters can be physically grouped into suspended and dissolved pollutants originating from organic and inorganic materials. Total Suspended Solids consist of organic and inorganic materials. The TSS value is used to determine the quality of waters because the higher the TSS value, the higher the pollutant material entering the waters. Based on the analysis results, the values on the first day of treatment A, B and C have the same value but experience different decreases each time, especially on day 42 for treatment A, which is 0.031 mg/l for treatment B, which is 0.023 mg/l and treatment C is 0.178 mg/l. It can be assumed that sea cucumbers play a very good role in utilizing waste, garbage, and dead parts that accumulate at the bottom of the waters as a source of nutrients for growth in IMTA system cultivation activities. Sea cucumbers utilize waste that is useful for eating leftover feed, feces, decaying waste and other organic materials (Firdaus *et al*., 2016). TSS values >500 mg/L will have a negative impact on the health of biota because particulate matter can cause blockage of the gills, which can lead to death (Setiyorini *et al*., 2022). TSS values describe the turbidity in waters that can affect the life of organisms in the waters. (Ambalika *et al*., 2021).

Ammonia is the main source of nitrogen for aquatic plants. High ammonia levels in water can cause the water to become cloudy and have an unpleasant odor (Erari et al., 2012). The ammonia levels obtained in treatments A, B, and C from the first day were 0 mg/l but increased on the 14th day, namely in treatment A of 0.39, then treatment B of 0.34 mg/l and treatment C of 0.36 mg/l. This is due to the activity of feeding and the metabolic process of the biota so that there is an increase but then decreases on the 28th day for treatment A of 0.27 mg/l, then treatment B of 0.24 mg/l and treatment C of 0.28 mg/l. and for the 42nd day there was also a decrease where in treatment A it was 0.03 mg/l, then treatment B of 0.20 mg/l and treatment C of 0.13 mg/l. Feeding can change the normal state of nitrogen compounds in nature. The main source of ammonia as a form of inorganic nitrogen in water is from the decomposition of organic matter, while the main source of organic matter is from the degradation process of feed residues and metabolic waste. This value is still feasible for cultivation activities. Because for marine biota the permissible range value for ammonia is 0.3 mg/l according to Government Regulation of the Republic of Indonesia No. 22.

Nitrate is the end product of the ammonia oxidation process and is safe because it is non-toxic to most fish species even at concentrations as high as 200 mg/l (Dauda *et al*., 2014). However, it can be a disturbance to the environment that causes eutrophication. The nitrate value on the first day of each treatment A. B and C had the same value of 0.02 mg/l then on the 14th day of treatment A it was 0.04 mg/l then treatment B was 0.01 mg/l and treatment C was 0.03 mg/l. Furthermore, on day 28, the nitrate value decreased in each treatment for treatment A, which was 0.03 mg/l, then treatment B was 0.01 mg/l, and treatment C was 0.02 mg/l. On day 42, the nitrate value for treatment A was 0.03 mg/l, then treatment B was 0.06 mg/l, and treatment C was 0.08 mg/l. Nitrate undergoes a reduction process by bacteria which can be utilized properly by seaweed to build and repair body tissues and as a source of energy needed in protein synthesis. So that the nitrate concentration in the IMTA system does not accumulate and does not become toxic to the environment for maintaining the biota of the IMTA system. Nitrate is absorbed and utilized by algae as the main ingredient for protein formation and chlorophyll formation for photosynthesis. The process of storing nitrate in inorganic materials or undergoing changes into ammonium through the enzymes nitrate and nitrite reductase. Amino acids can also be formed through glutamine synthetase and glutamate synthetase (Roleda & hurd, 2019).

Temperature is a physical parameter used to see the effect of the life patterns of aquatic organisms. The temperature value of each treatment is still in the ideal range for the life of biota maintained in the IMTA system. A good temperature for seaweed growth is around 20-28°C, while a good temperature for white snapper growth is around 28-32°C. (Widowati *et al*., 2019) For sea cucumber growth, the appropriate temperature is 26-30°C. (Sulardiono *et al*., 2017).

One of the factors that affects salinity is temperature. If the temperature increases, the salinity will increase, this is due to the evaporation process of sea water (Jaya *et al*., 2022). The salinity value of the waters during the study was ideal for the life of biota in the IMTA system where for the growth of snapper the salinity value was 5-25 ppt and for the growth of seaweed it ranged from 15-30 ppt (Widowati *et al*., 2019). Meanwhile, sea cucumbers can live in waters with a salinity of 30-34 ppt, but some types of them can survive with a salinity of 21 ppt. Changes in salinity are influenced by the layout of the waters, if those directly adjacent to land tend to have low salinity values and change due to freshwater input, while those directly adjacent to the open sea have high and stable salinity values (Hasnia, 2022)

Dissolved oxygen in water comes from air diffusion and the results of photosynthesis of aquatic plants, both micro (phytoplankton) and macro (seagrass, macro algae, mangroves). Dissolved oxygen content for white snapper and sea cucumber commodities. The ideal dissolved oxygen range for white snapper is 3.5 mg/l (Widowati, 2019), while for sea cucumbers it is 4-9 mg/l (Sulardiono *et al*., 2017). If the dissolved oxygen value is not balanced, it will cause stress to the fish due to the lack of oxygen supply to the brain and can cause death because the fish's body tissue is unable to bind dissolved oxygen in the blood (Dahril *et al*., 2017).

The degree of acidity (pH) is a parameter that can show the level of balance between chemical elements in an aquatic ecosystem (Jaya *et al*., 2022). The pH value can be used as an indication of the good or bad condition of a body of water. The pH conditions of the water during the study were quite good for the growth of cultivated biota maintained in the IMTA system. The value of the water acidity (pH) based on the results of the pH level study is also still included in the standard for marine water quality determined by Government Regulation of the Republic of Indonesia Number 22, which is at a pH range of 7-8.

CONCLUSION

The IMTA system can help to reduce organic waste with a picture of a decrease in TOM, TSS, ammonia and nitrate values, in addition to water quality parameters are also in a state that is suitable for the life of each biota at different trophic levels. This illustrates the existence of an ecosystem balance in cultivation activities that are well maintained and provide mutual benefits.

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REFERENCES

Ambalika, I., Nugraha, M. A., Pamungkas, A., Utami, E., Akhrianti, I., Hudatwi, M., Sari, S. P. & Marfuah, T., (2021). Sebaran Partikel Tersuspensi, Partikel Terlarut dan Laju Sedimentasi di Teluk Kelabat Luar, Area Pengaruh Penambangan Timah. *Scientific Timeline*, *1*(2), 97-107.

Aonullah, A. A., Ritonga, L. B. R., Nisa, A. C., Fahruddin, F., & Nazran. (2024). Analisis Dampak Lingkungan (AMDAL) pada Sektor Budidaya Laut dengan Sistem Keramba Jaring Apung (KJA) di Perairan Teluk Ekas Lombok Timur Nusa Tenggara Barat. Lemuru: *Jurnal Ilmu Perikanan dan Kelautan Indonesi*a, *6*(1), 101-114.

Dahril. I., Tang, U. M., & Putra, I. (2017). Pengaruh Salinitas Berbeda Terhadap Pertumbuhan dan Kelulusanhidupan Benih Ikan Nila Merah (*Oreochromis* sp.). J*urnal Berkala Perikanan Terubuk*, *45*(3), 54-68.

Dauda, A. Babatunde., & Akinwole, A. O. (2014). Interrelationships Among Water Quality Parameters in Recirculating Aquaculture System. *Nigerian Journal of Rural Extension and Development*, 8, 20-25.

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A.S., & Akonwole, A. O. (2019). Waste Production in Aquaculture: Sources, Components and Management in Different Culture Systems. *Aquaculture and Fisheries*, 81-88.

Erari, S. S., Jubhar, M., & Karina, L. (2012). Pencemaran Organik di Perairan Pesisir Pantai Teluk Youtefa Kota Jayapura, Papua. P*rosiding Seminar Nasional Kimia Unesa*. ISBN : 978 – 979 – 028 – 550 – 7 Surabaya, 25 Februari 2012 C - 327.

Firdaus, M., Indriana, L. F., Dwiono, S. A. P., & Munandar, H. (2016). Konsep dan Proses Alih Teknologi Budidaya Terpadu Teripang Pasir, Bandeng dan Rumput Laut. *In Seminar Nasional Technopreneurship dan Alih Teknologi* (Vol. 2, pp. 51-63). Bogor. Pusat Inovasi LIPI.

Gustiyo, P. E. (2021). Studi Kandungan TOM dan BOD Berdasarkan Kedalaman Berbeda Sekitar Aktivitas Keramba Jaring Apung (KJA) Berlapis di Waduk PLTA Koto Panjang Kabupaten Kampar Provinsi Riau. *Jurnal Sumberdaya dan Lingkungan Akuatik*, *2*(2).

Hasnia, W., Ramli, M. & Rahmadani. (2022). Struktur Komunitas Holothuroidea di Perairan Desa Sombu Kabupaten Wakatobi. *Sapa Laut*. *7*(1), 45-51.

Jaya, L. S. S., Junaidi, M., & Diniarti, N. (2022). The Effect of Seed Weight on Growth of Seaweeds *Kappaphycus alvarezii* in Integrated Marine Aquaculture of Ekas Bay, East Lombok Regency. *Jurnal Biologi Tropis*, *22*(2), 629-640.

Kusen, D. J. (2014). Aktivitas Budidaya Keramba Jaring Apung dan Kontribusinya Terhadap Eutrofikasi dan Sedimentasi di Danau Tondano Kabupaten Minahasa Provinsi Sulawesi Utara. *Disertasi*. Universitas Brawijaya. Malang. 167 hal

Mustofa, A., Hastuti, S., & Rachmawati, D. (2018). Pengaruh Periode Pemuasaan Terhadap Efisiensi Pemanfaatan Pakan, Pertumbuhan dan Kelulushidupan Ikan Mas *(Cyprinus Carpio)*. *Journal of Aquaculture Management and Technology*, *7*(1), 18–27.

Pattinasarany, M. M., & Manuputty, D. G. (2018). Potensi Jenis Teripang Bernilai Ekonomis Penting di Ekosistem Padang Lamun Perairan Desa Suli Maluku Tengah. *Jurnal Papalele*, *2*(1).

Peraturan Pemerintah No. 22 Tahun 2021 Tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup.

Roleda, M. Y., & Hurd, C. L. (2019). Seaweed Nutrient Physiology: Application of Concepts to Aquaculture and Bioremediation. *Phycologia*. 58(5): 552-562. https://doi.org/10.1080/00318884.2019.1622920

Setiyorini., Yasa. N. G., Purwanto, J. Prabowo, W. T., & Putra, S. A. A. M. (2022). Potensi Padatan Tersuspensi (TSS) Limbah Budidaya Udang Vaname (*L. vannamei*) Sistem Bioflok sebagai Sumber Bahan Baku Pakan Alternatif. *Journal of Fish Nutrition*, *2*(2) https://doi.org/10.29303/jfn.v2i2

Sulardiono, B., Purnomo, P. W., & Haeruddin, H. (2017). Tingkat Kesesuaian Lingkungan Perairan Habitat Teripang (Echinodermata: Holothuroidea) di Karimunjawa

(Environmental Suitability for Holothuroidea Habitat in Karimunjawa). *Saintek Perikanan: Indonesian Journal of Fisheries Science and Technology*, *12*(2), 93.

Triarso, I., & Putro, S. P. (2019). Pengembangan Budidaya Perikanan Produktif Berkelanjutan Sistem IMTA (*InIntegrated Multi-Trophic Aquaculture*)(Studi Kasus di Kep. Karimunjawa, Jepara). *Life Science*, *8*(2), 192-199.

Widowati, L. L. S., Rejeki, R. W. Ariyati, & R. H. Bosma. (2019). *Petunjuk Budidaya Tambak Terpadu (IMTA) Integrated Multi Trophic Aquaculture*. Semarang. PASMI. 22 hlm.

Yuniarsih, E., Nirmala, K., & Radiarta, I. N. (2014). Tingkat Penyerapan Nitrogen dan Fosfor pada Budidaya Rumput Laut Berbasis IMTA (*Integrated Multi Trophic Aquaculture*) di Teluk Gerupuk, Lombok Tengah, Nusa Tenggara Barat. *Jurnal Riset Akuakultur*, *9*(3), 487.

Zamora, L.N., Yuan, X., Carton, A. G., & Slater, M. J. (2016). Role of Deposit-Feeding Sea Cucumbers in Integrated Multi Trophic Aquaculture: Progress, Problem, Potential and Future Challenges. *Reviews in Aquaculture*. 1-18.